Pneumatic conveying
for the pharmaceutical industry

PRODUCTION IN THE PHARMACEUTICAL SECTOR REQUIRES INTERDISCIPLINARY SKILLS WITH A HIGH LEVEL OF AUTOMATION. A MAJOR PROBLEM IS THE TRANSFER OF BULK MATERIALS, TYPICALLY POWDERS OR SOLIDS. THE USE OF PNEUMATIC CONVEYING SYSTEMS OFFERS GOOD SOLUTIONS, ALSO IN VIEW OF THE EXTREME CLEANLINESS REQUIRED. DIFFERENT TYPES OF AIR CONVEYORS CAN MEET DIFFERENT NEEDS.

The pharmaceutical industry is a very important sector in the Italian economy. The sector covers all activities related to research, development, production and marketing of medicines for human and veterinary use, as well as other products such as cosmetics and food supplements. Therefore, it is a rather extensive and articulated strategic sector. Its importance can be underlined by referring to data made available by companies that develop and produce medicines, especially on behalf of large multinationals corporations. This group of companies is identified by the acronym CDMO (Contract Development and Manufacturing Organisation). According to a survey presented in 2021, the budgets of Italian CDMO companies reached a turnover of approximately EUR 2.3 billion in 2019, accounting for 23.3 per cent of the entire European turnover and ranking first, ahead of Germany (EUR 2.1 billion) and France (EUR 1.9 billion). In the pandemic years, the sector experienced further growth. In particular, injectable production increased by 34% in 2020 compared to 2019, while growth in 2021 was 4% compared to 2020. Also notable is the change in high-tech and biotech productions, up 11% between 2020 and 2019 and 13% between 2021 and 2020. Overall, the sector is very dynamic, with a strong propensity to export, especially to highly developed countries: almost 70% is exported to the United States, the European Union and Japan. The pharmaceutical industry's production involves numerous disciplines, starting with chemistry, biotechnology and medicine, with a strong presence of mechanics, robotics and automation in general. The latter is absolutely essential for an industry where production levels are high and production cycles are very often quite complex and can take place either with continuous lines or with batch processing. A typical need is to transfer between different processing or storage stations bulk products, which may be powders, granules, tablets or other. If we associate this need with the importance of extreme cleanliness, which is always associated with pharmaceutical production, a transfer in a closed and protected environment is a priority. A good solution is offered by air transport systems in which the material is moved by air inside a tube, in different ways depending on the process, but always in a way that preserves the integrity of what is being transferred. In the article, some types of pneumatic conveying systems, in which compressed air is used to push or vacuum is produced to suck in what is needed, will be shown, and the conditions of use will be indicated. Examples of industrial applications in the pharmaceutical field will also be presented.

Pneumatic conveying for bulk product handling

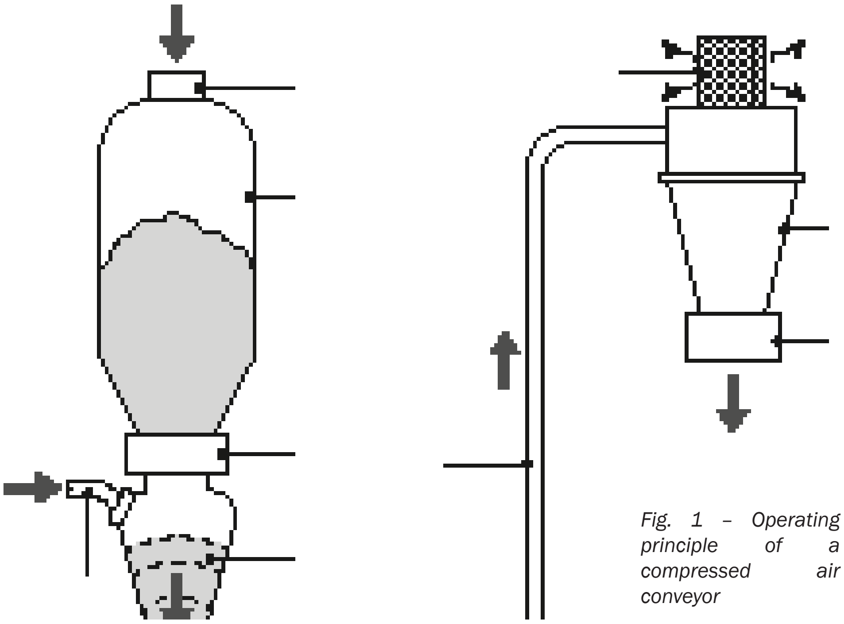


Fig. 1 – Operating principle of a compressed air conveyor

Pneumatic conveying is used in many industries for the handling of bulk products, which are moved by simply sliding them through a tube rather than by handling containers with more complex solutions. The transfer occurs through the interaction between the material to be moved and a gas moving at a certain speed, driven by a pressure difference. Normally, the gas used is air, available everywhere and moved by compressors or vacuum pumps. In some special cases, as happens in the transport of potentially explosive materials or for easily oxidisable products, a different gas may be used, notably nitrogen, which is inert and does not react with the material it comes into contact with. The movement of the material takes place between an accumulation tank 1 and a final collection tank 3. A thruster 2 connected to the accumulation tank by a valve 5 is used for the thrust. 6 indicates the connecting pipe between the thruster and the final tank. Initially, the reservoir 1 is filled via the upper supply port 4. By opening valve 5, the material descends to the bottom and fills the thruster. Once filled, compressed air is supplied via tube 7 and the air pushes the material into the pipe 6. At this point the transfer takes place in a manner that may differ from case to case, as will be shown below. At the end of the transfer all the material contained in the thruster reaches the tank 3, from which it can be discharged by opening a valve 8. A filter is indicated by 9, which allows excess air to be expelled to the environment during the transfer of the material and retains the material within the system. Movement can take place in different ways, depending on requirements, with an intermittent flow or a continuous flow. The system as a whole is simple, easy to apply and can be easily integrated into production processes. For these reasons, air-assisted transport is a widely used system in industry to transfer materials to different points in a plant and between different processing stations via closed pipelines. The applications involve the most diverse sectors. Examples include the construction industry (moving powdered cement), foundries (moving sand for moulds), the textile industry (moving fibres), agriculture (moving grain, grains, seeds and various other products), the food industry (flour, mixing powders, ...), and the pharmaceutical industry. In the latter case, various processes of mixing, processing, granulation, concentration and packaging can be found, involving both powder preparations, as well as capsules, tablets and other finished products.

Fig. 2 – 'Ready Mix' dense phase pneumatic conveyor system

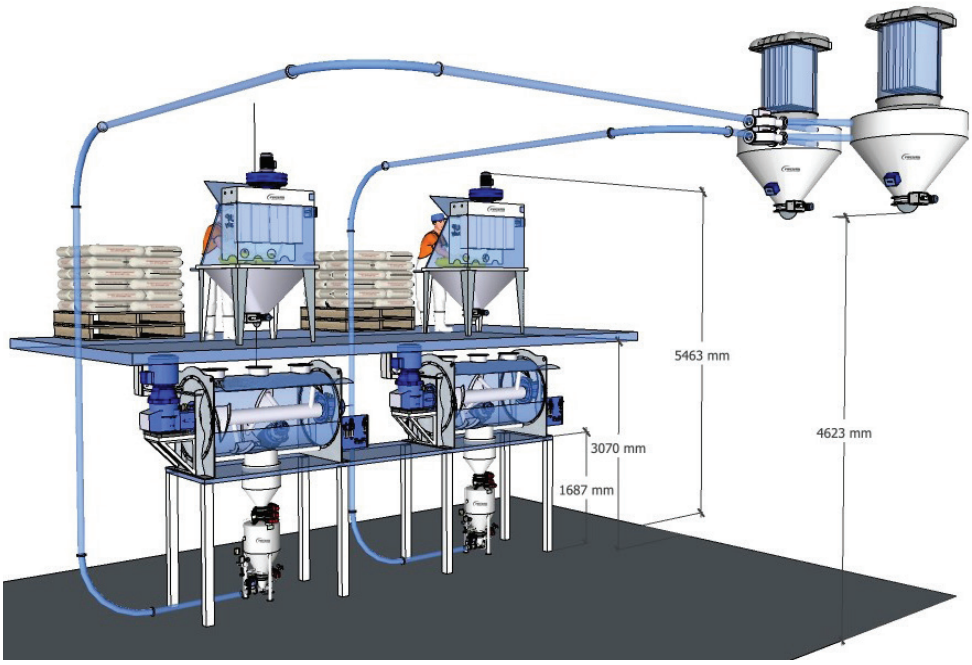


Fig. 3 – Technical compartment with lobe pumps

Fig. 4 – Manual bag emptying station

Different types of pneumatic conveying

In industrial applications, the need to transport granular or powdered materials can be solved with pneumatic conveyors that move these substances inside pipes, generally circular, in fluid suspension by means of an air current of suitable velocity. The various types of pneumatic conveying differ in the way in which the movement of the material is achieved: by means of an air current in vacuum (suction) or with pressurised gas (thrust). A second difference is the type of material movement: intermittent or continuous. The main types of pneumatic conveying that can be used, particularly in the pharmaceutical sector, are then considered.

They are:

a) Pneumatic conveying under pressure, in dense phase;
b) Pneumatic conveying under pressure, in dilute phase;
c) Pneumatic conveying in vacuum, dense phase;
d) Vacuum pneumatic conveying, dilute phase.

The different conveying systems perform differently and are therefore used according to the specific requirements of each application.

a) Pneumatic conveying under pressure, dense phase

Pneumatic conveying under pressure uses compressed air as a propulsion medium to propel the material to be transferred, as shown in figure 1. In general, it allows longer distances to be covered than suction systems In dense phase pressure conveying, a rather low transport speed of between 2 and 10 m/s is used. This speed, which is lower than in dilute phase conveying, allows the integrity of the product to be preserved by limiting changes in bulk density and particle size to a minimum. The use of dry, low-temperature compressed air preserves the characteristics of the product being transported. The ratio between the product conveyed and the air used is very high. The system operates with low air consumption and no electric motor running all the time, resulting in low energy consumption. The use of little air allows oxidation to be limited and the low speed ensures low pipe wear. For good wear behaviour and preservation of the material moved, the conveyors can be made of painted iron, AISI 304 or AISI 316 stainless steel. The advantage of this type of conveyor is the absence of problems in the event of a power failure. Contrary to what happens in more traditional systems, in which a forced interruption of the conveyance causes the line to be disarmed and must be emptied to restart it, the dense phase conveyor can stop and restart at any time without any need for extraordinary intervention. As far as management modes are concerned, there are different types, with discontinuous flows or with continuous flows, suitable for different situations. Batch flows occur when there are phases in which batches of material are transferred, followed by phases in which the transport is interrupted. Batch transport referred to as empty pipe transport (or 'batch' transport) involves discontinuous operation whereby all the material, loaded into the thruster, is pushed along the pipe to its destination by compressed air. At the end of this phase, the thruster and the pipe remain completely empty and all the material loaded in the thruster has been transferred to the destination. This type of transport is suitable for short to medium distances, up to about 50-60 metres. Transport with a full pipe involves operating cycles whereby the thruster is alternately filled and emptied, moving the material contained in the initial section of the pipe. In this way the material is moved little by little along the pipe. After filling the line, the material starts to be unloaded at the destination at very low speeds. This type of transport is suitable for very long distances (over 100 metres) and/or for transporting very fragile or very abrasive materials. Continuous flows occur when there is only one phase in which the material is transferred without interruption of transport. In this case, we speak of continuous full pipe conveying and the use of two thrusters operating alternately in parallel, pushing the material through the same pipe. Figure 2 shows a rendering of a 'Ready Mix' dense-phase pneumatic transfer system by RGS Vacuum Systems, a leading company in the pneumatic conveying sector. In this system, the product arrives in batches of bags and is gravity fed by the manual bag emptying station into a rotary mixer. The figure shows two loading stations with pallets and sacks at the top of the system and two mixers below. At the bottom is the thruster that is fed by the mixer. By means of a dense-phase conveying pipe, the product finally reaches the receiving hoppers, located at the top right, and feeds the filling machines. The system is intended for the processing of environmentally friendly pesticides, mushrooms and maltodextrins. RGS Vacuum Systems pneumatic conveying systems are customised according to customer requirements and are available with PED, ASME and ATEX certification. All in all, dense phase pneumatic pressure conveying systems can be used advantageously when large quantities of powders or granules, fragile materials, very abrasive materials, or product mixtures that must remain homogeneous must be conveyed, from a few metres up to large distances (over 100 m). Flows can reach tens of tons/h. In many cases, the system proves to be the best conveying technology, as the low speeds preserve the integrity of the product and avoid wear and tear on the equipment. The ease of cleaning is also important.

b) Pneumatic dilute phase pressure conveyors

The characteristic feature of dilute phase pneumatic pressure conveying systems is that they have a pressure generator (often represented by a suitable pump) positioned upstream of the system. Therefore, all the pipes and the various components are in excess pressure with respect to the atmosphere. The material is injected into the pipe, which allows it to be transported to its final destination, by means of a forced injection system, which engages the pipe itself. Depending on requirements, the product can be fed by means of a sealed rotary feeder or a compressed air injector. At the arrival points, the product is separated from the conveying air by means of filters. Pneumatic conveying under pressure in the dilute phase works by fluidising the material, i.e. dispersing it in the conveying air. The various elements or granules conveyed thus tend to be separated from each other, resulting in a low-density whole.

Fig. 5 – Bag Emptying Station

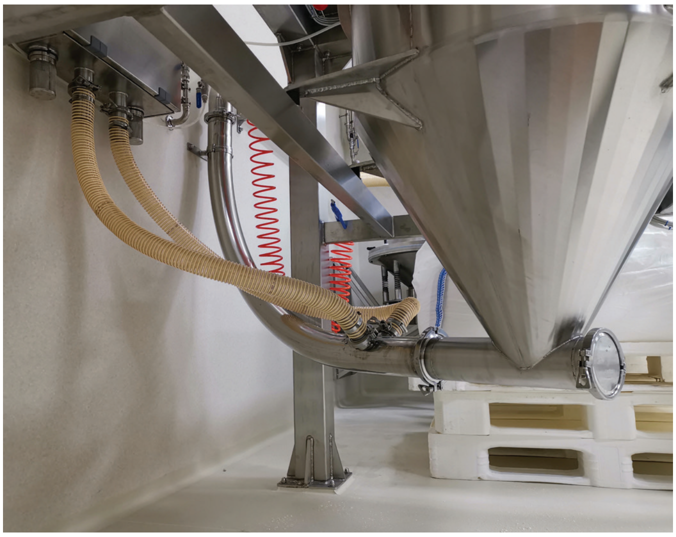


Fig. 6 – Details of the bag emptying station

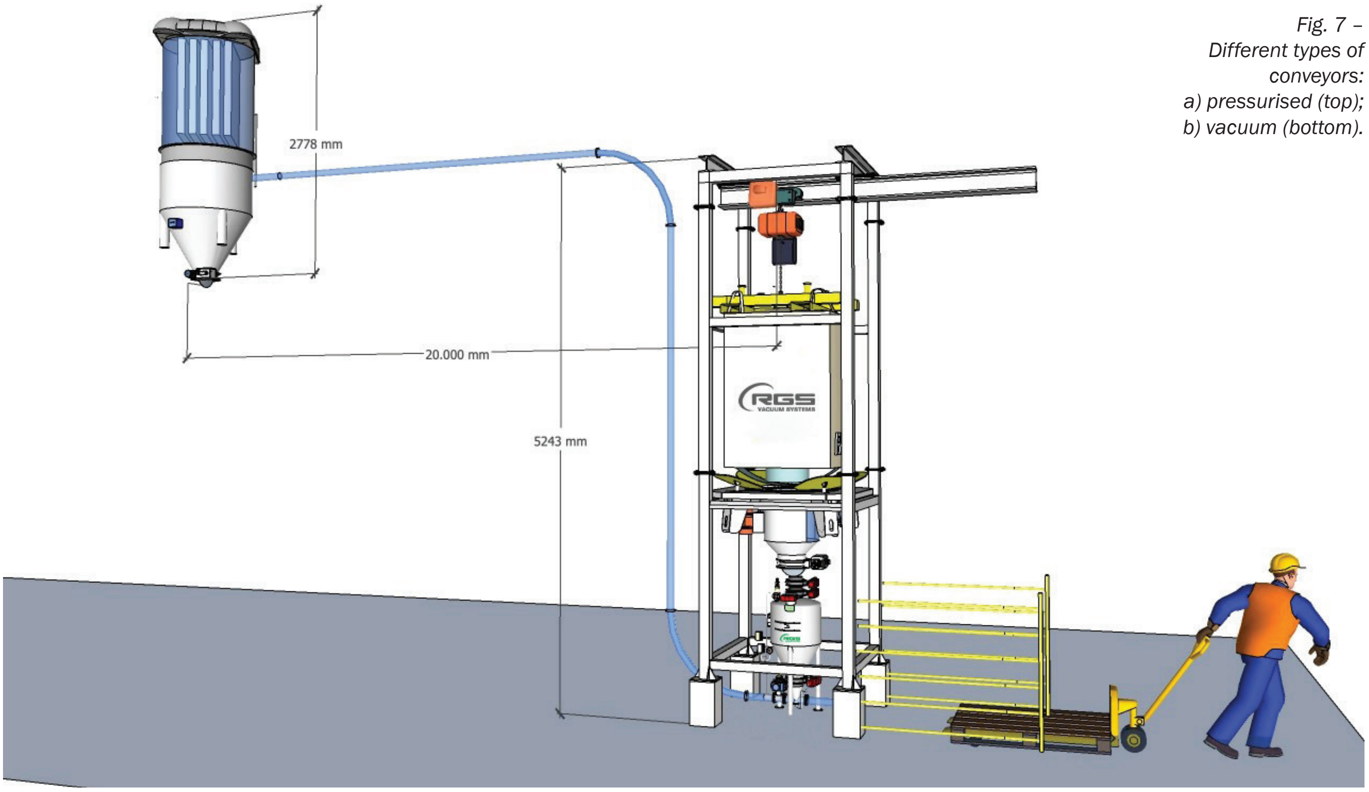
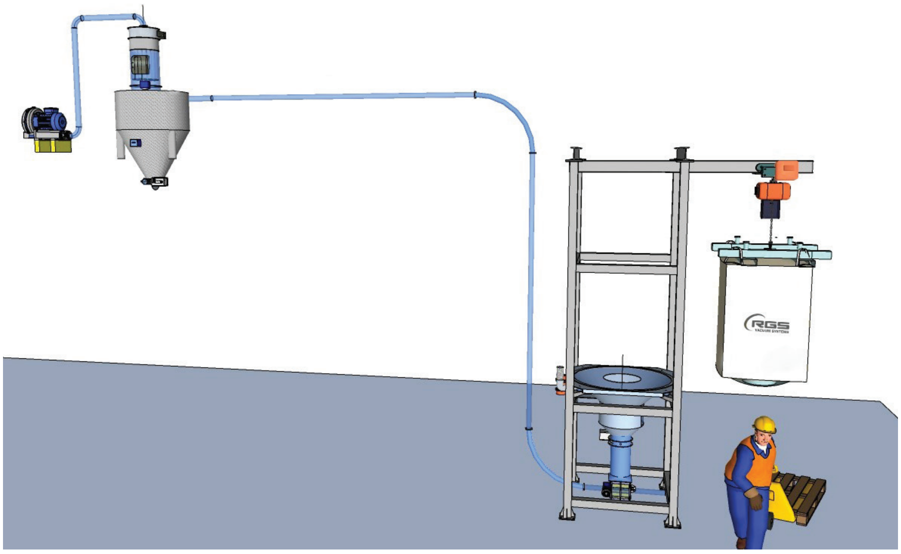


Fig. 7 – Different types of conveyors: a) pressurised (top); b) vacuum (bottom).



c) Pneumatic conveying in vacuum, dense phase

In pneumatic vacuum conveying, the pressure difference required to produce a gas flow is achieved by creating a vacuum downstream of the conveying tube, instead of pushing with pressurised gas upstream.In this type of conveyor, a vacuum is therefore generated inside the pipe and the product is sucked from the pick-up point to the discharge point through the conveying tube. The suctioned material is sent through a pipe into a container, where the separation of product and air takes place. The air sucked in during transport is purified by a filter and expelled from the vacuum source. The entire process is managed by a control unit. With this type of transport, the air velocity is further reduced compared to pressure conveyors, to values of less than 10 m/s and the vacuum reaches over 800 mbar. The air velocity is not sufficient to keep the particles inside the tube in flight. Therefore, the material tends to remain compact and is conveyed in blocks, interspersed with gaps. The low speed enables gentle handling of materials and is suitable for viscous, abrasive products, mixtures, very fragile products (rice, fibreglass, ceramic atomisers, etc.), and liquids. Advantages include the low crushing of products, the small size of the hoppers and various apparatus such as pipes and vacuum pumps, small filtering surfaces, and good internal cleaning. For vacuum generation, units with side or lobe channels are used with capacities from 2000 to 3000 m^3/h with an acoustic cabinet and equipped with a suction filter and optional ventilation unit. All units are also equipped with analogue or digital pressure indicators for easy control. Figure 3 shows a technical compartment in which lobe vacuum cleaners with wall-mounted control panels are installed. Figure 4 shows a manual bag emptying station with dedusting system. The product to be handled is sucked in directly from the base of the hopper. Figure 5 shows a bag emptying station, also referred to as a big-bag station. Such a station is one of the possible loading stations for a product to be handled with a pneumatic conveyor. In general, material can be taken from either a big-bag or a sack-emptying station, as seen in figure 4. In both cases, however, the material taken passes through a vibrating screen where lumps or any foreign bodies are blocked and discarded. Figure 6 shows a detail of the bottom of the big-bag emptying station. The product is sucked in and mixed with air, modulating the supply with the use of two different control valves.

d) Pneumatic conveyors in vacuum, diluted phase

The conveyor operates with a vacuum and generates a vacuum within the conveying pipeline, whereby the product is sucked from the pick-up point towards the conveyor. The material picked up is sent through a pipe into a container, where the separation of product and air takes place. The sucked air is finally purified with a filter and expelled to the outside by the vacuum pump. Pneumatic transport in the dilute phase, or low pressure, is characterised by the low value of the mass concentration ratio of the product per m^3 of air. The air velocity inside the pipes is generally between 20 and 40 m/s with a maximum vacuum of 400/500 mbar. The product particle velocity is significantly lower, but such that the material cannot be deposited inside the conveying line. Advantages include: the possibility of continuous operation of the conveying system; easy operation and maintenance of the equipment; cost-effective operation; and the possibility of reaching long distances. Vacuum pneumatic conveying in dilute phase is particularly suitable for the pharmaceutical, cosmetic, chemical, food and confectionery industries.

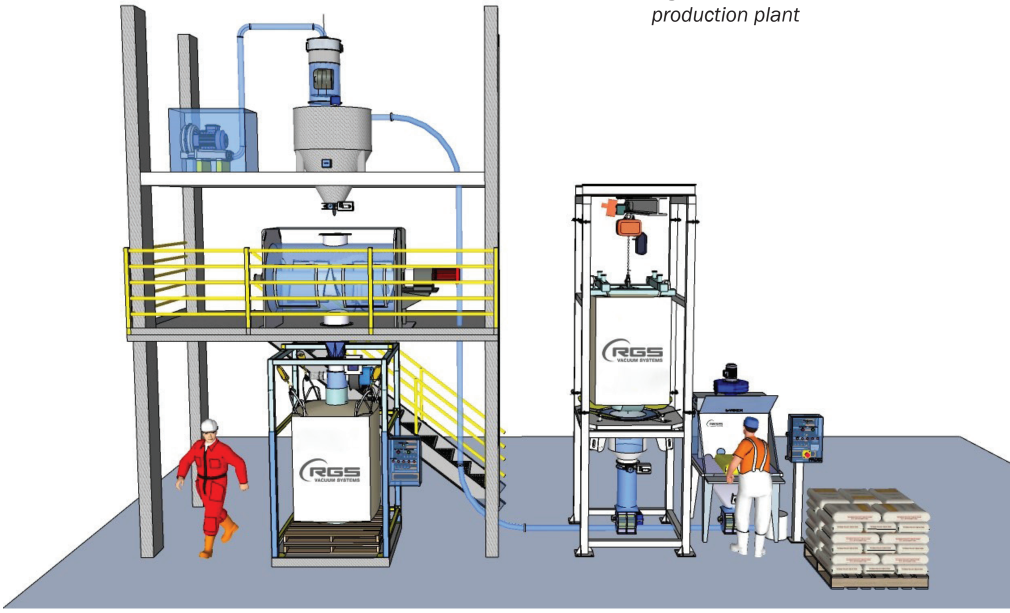


Fig. 8 – Food supplement production plant

It is recommended for the handling of powders and granules, non-abrasive materials and less fragile materials. The different configuration between pneumatic pressure transfer systems and vacuum transfer systems is clarified by figure 7. Figure 7a shows an example where material is loaded with a big-bag emptying station and transferred to a receiving hopper visible at the top left. On the hopper is a large air exhaust filter. In figure 7b, the material is moved by a vacuum conveyor starting with a big-bag loading station. On the receiving hopper, also at the top left, is a filter connected to a vacuum pump.

Fig. 9 – Mixer: a) introduction of the first product (above); b) introduction of the second product (below).

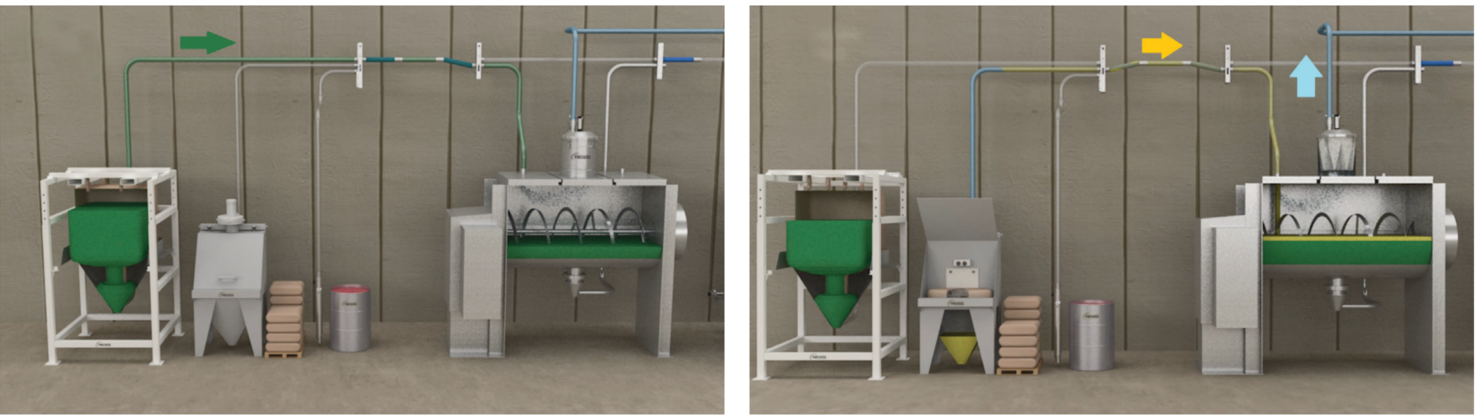


Fig. 10 – Disassembled bag / sleeve filter.

Specific requirements and applications in the pharmaceutical sector

The preparation and packaging of pharmaceutical products require certain important conditions to be fulfilled that are linked to the specificity of the application. Amongst these, it is worth mentioning that material intended for direct interaction with humans is handled. Therefore, not only clean conditions must be guaranteed, but often also the need to avoid any contamination. All this is reflected in the choice of materials, the definition of filtration systems, and the need to isolate what is being handled from the outside. Pneumatic transport, in which everything is moved inside closed tubes, with filters and protection, meets this need. Another condition is that of not damaging the materials, especially when it comes to finished products (capsules, tablets, etc.).

From this point of view, an air conveyor, applied with the right operating conditions, appears very suitable. In fact, air can act as a means of supporting and isolating the elements to be moved, preventing significant creep, shock and related abrasion and breakage. Pneumatic conveying is widely used in the pharmaceutical industry, with various applications, as the photographs show. Figure 8 shows the configuration of a plant for the production of food supplements (whey protein/collagen/amino acids/maltodextrins/vitamins). The system includes a mixing and filling plant from big-bags and bags with pneumatic feeding. All parts in contact with the product are made of AISI 304 steel. The raw material arrives in sacks and bags, is fed to the ground floor via the big-bag emptying station and the manual bag emptying station. The pneumatic conveyor takes place under vacuum, the mixture is fed to the mixing tower and is processed with the subsequent filling of the next big-bag. 1800 g pots and 500 g and 1000 g bags are filled. Figure 9 shows a rendering of a work station where two different products are mixed by a spiral mixer. The transfer from the loading station of the products to the mixer takes place by pneumatic conveying. In figure 9a, the first product (shown in green) is fed and in figure 9b, the second product (shown in yellow) is transferred. In all applications, filters are used extensively to separate the air from the products being handled; this is particularly important in the case of dusty products. Figure 10 shows one of the filter types disassembled (bag / sleeve filters).

IN CONCLUSION

The pharmaceutical sector is rather complex, with a variety of activities ranging from the preparation of substances, to the manufacturing process of products, to their packaging. At various stages of the process it is necessary to handle bulk material, from powders to granular products (semi-finished or finished products). The use of pneumatic conveying systems facilitates the handling of bulk products and facilitates the production process. Different requirements can be adequately met by different air conveying solutions. Once again, pneumatics proves to be a multifaceted technology, which works alongside others to solve a wide variety of problems in the best possible way. We would like to thank RGS Vacuum Systems for their cooperation and for providing photographic material.

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Via Mavore 1640/C - 41059 Zocca (MO) Italy
Tel. +39 059.986833 | info@rgsvs.com
www.rgsvacuumsystems.com